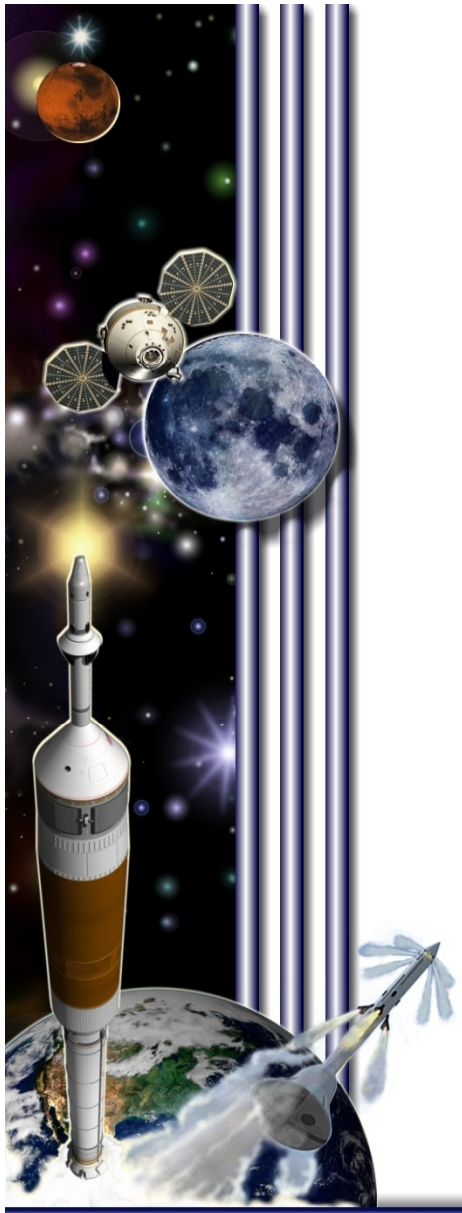


Groundwater Remediation and Alternate Energy at NASA White Sands Test Facility

November 18-20, 2008

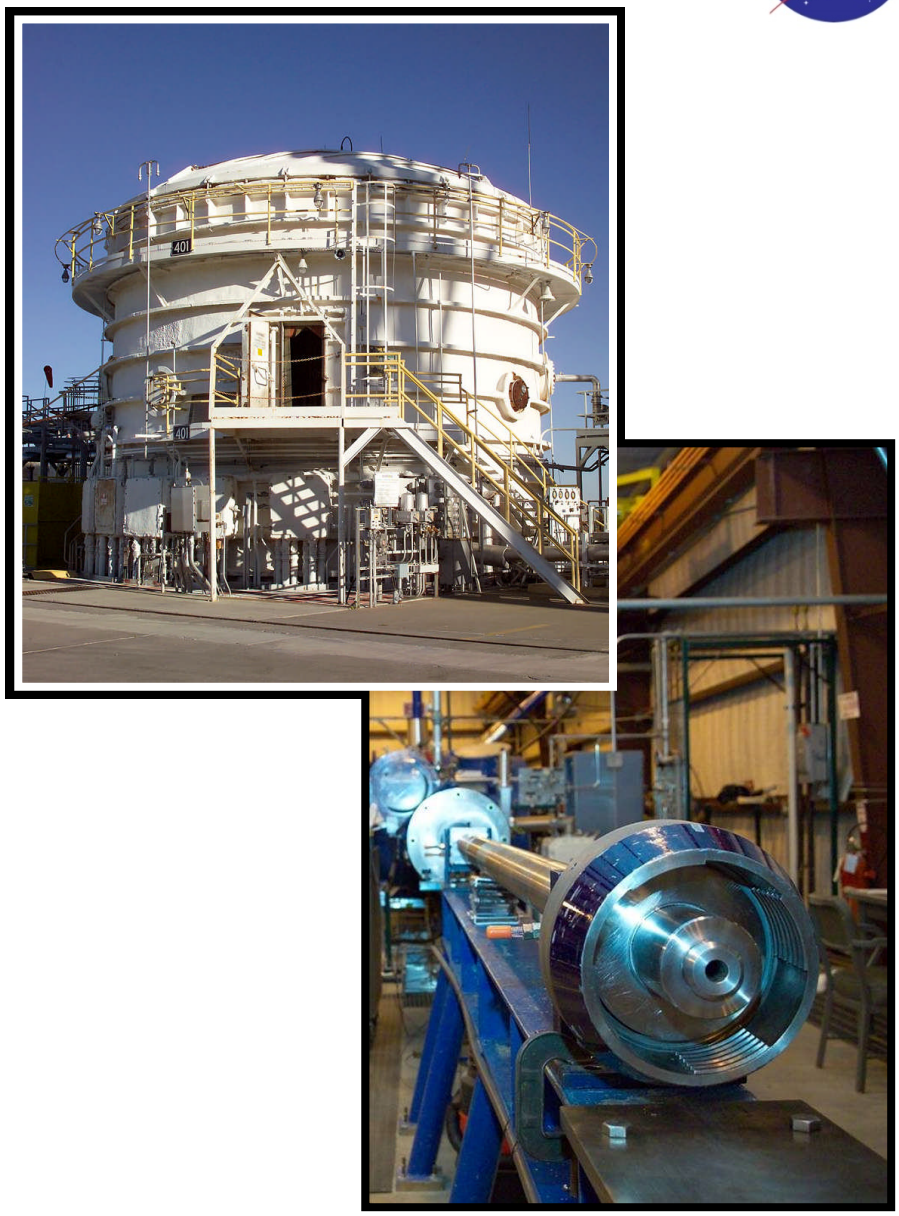
Holger Fischer
Facility Operations
NASA White Sands Test Facility

Content

- White Sands Test Facility (WSTF) Overview and Core Capabilities
- WSTF Groundwater Remediation Program
- Alternate Energy Programs
  - Wind Energy
  - Solar Testbed
    - Solar
    - Vehicle Plug-in
    - Energy Storage
  - Utility-Size Peak Shaving Solar Generation Plant

WSTF Core Capabilities

- Remote Hazardous Testing of Reactive, Explosive, and Toxic Materials and Fluids
- Hypergolic Fluids, Materials, and Systems Testing
- Oxygen Materials and System Testing
- Hypervelocity Impact Testing
- Flight Hardware Processing
- Propulsion Testing



Remote Hazardous Testing

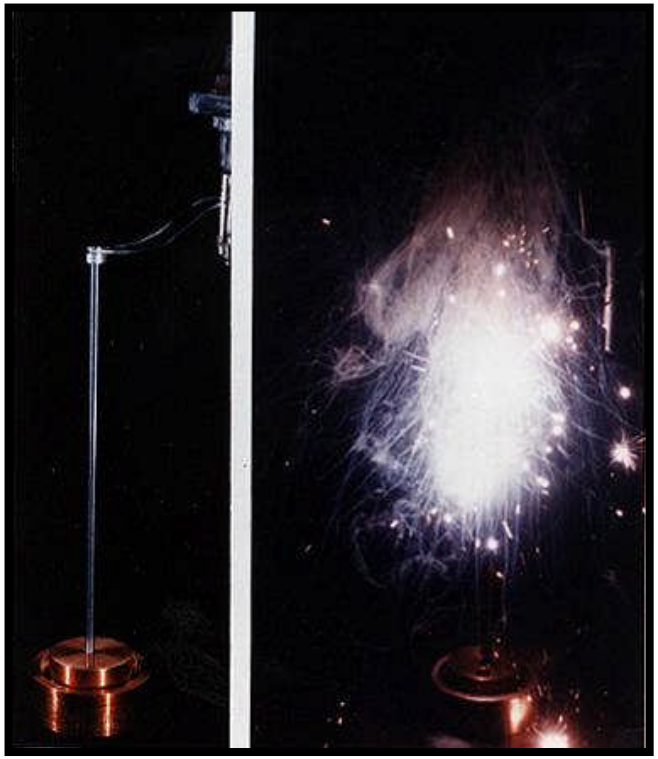
Reactive, Explosive, and Toxic Materials and Fluids

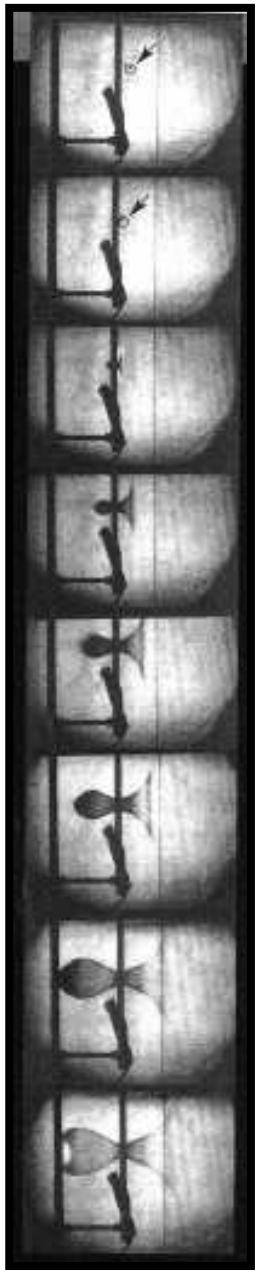
2000 lbs LH_2/LO_2 Test

Solid Propellant Test

500 lbs LH_2/LO_2 Test

Laboratories

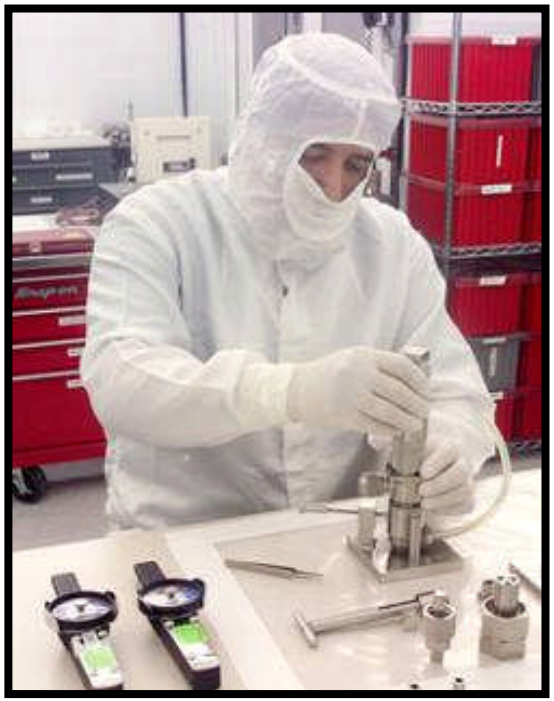




- Micrometeoroid/Debris Hypervelocity Impact Testing
- Propellant and Explosion Hazards Assessment
- Research on Flammability of Materials including Metals in Oxygen-enriched Atmospheres

Hardware Processing

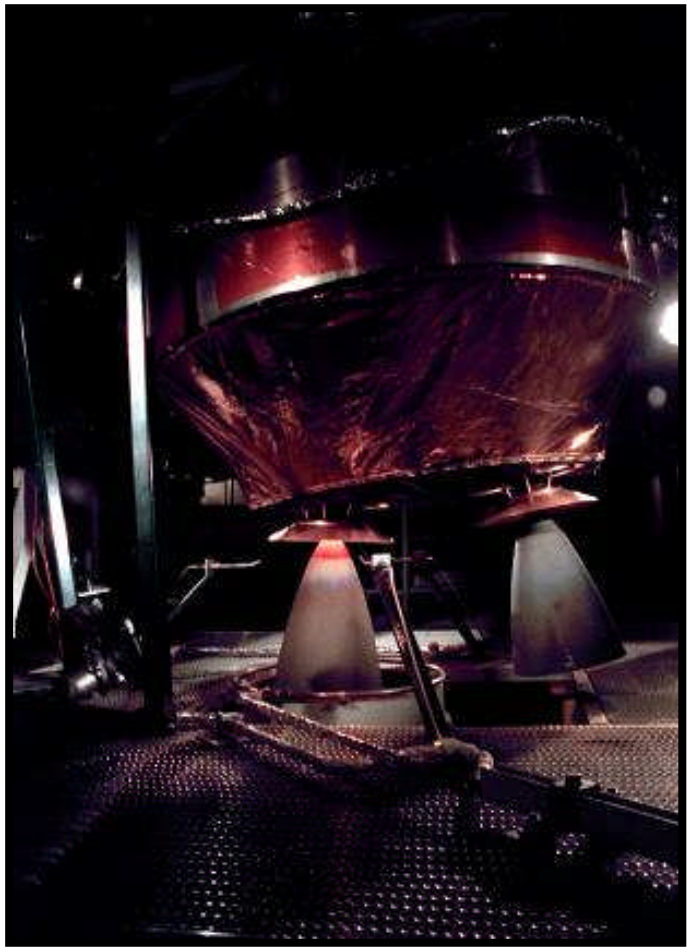
Flight Critical System
Components Refurbishment



Critical Flight
Hardware
Assembly

Flight
Hardware
Production

Propulsion Test

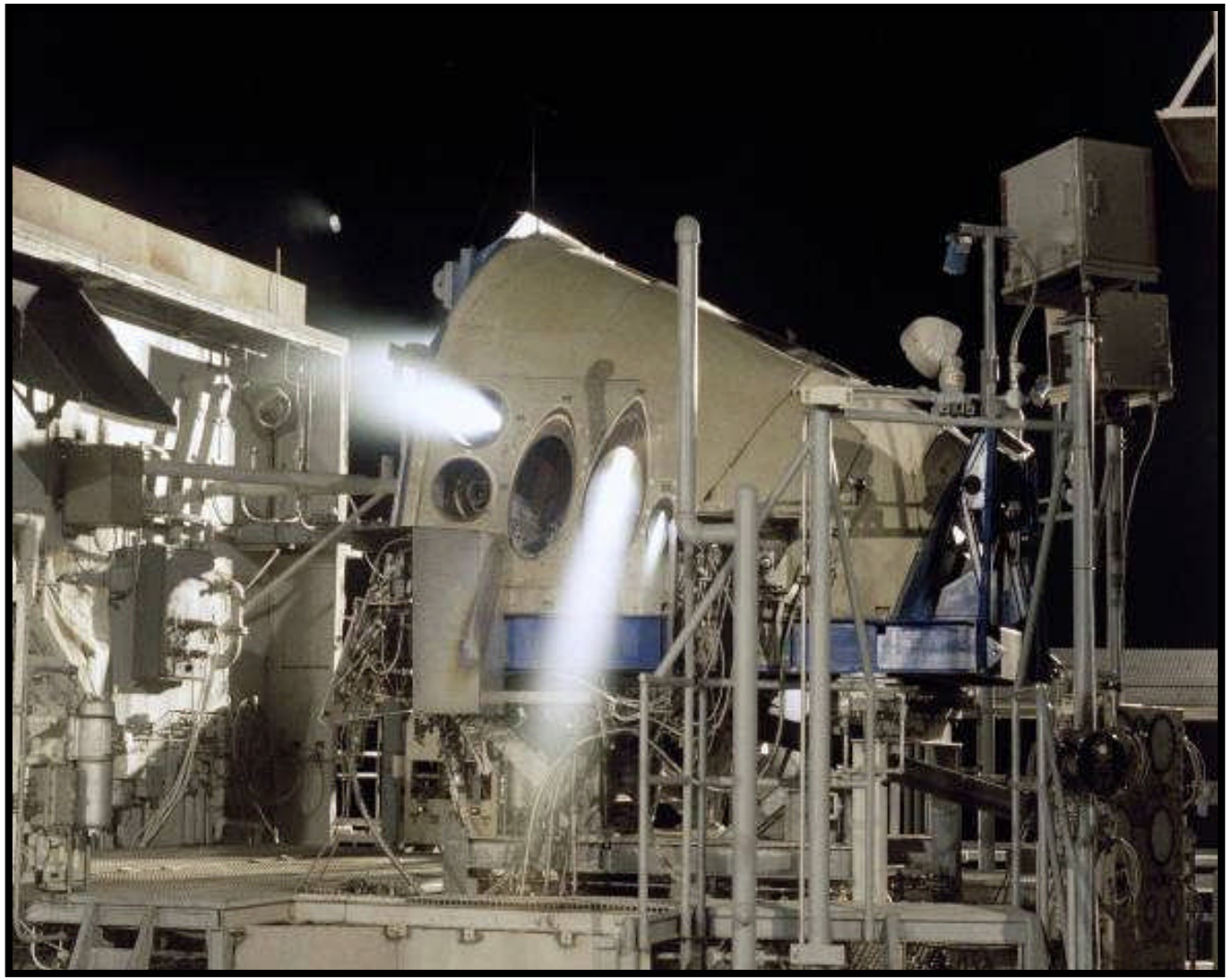


Cassini – Saturn Orbit Insertion
Engine Glows during 3-h
20-min Continuous Firing

Shuttle PRCS Thruster
Hot-fire Testing

Minuteman Qualification Firing
inside Vacuum Test Cell

Propulsion Test



Night Firing of Shuttle Forward RCS Primary and Vernier Thrusters

Restoration Program

- Historic operations and practices in the1960s resulted in contamination of WSTF's groundwater.
  - Propulsion system testing programs:
    - N-Nitrosodimethylamine (NDMA)
    - Dimethylnitramine (DMN)
  - Component servicing and cleaning operations:
    - Trichloroethene (TCE)
    - Tetrachloroethene (PCE)
    - Freons: (11, 21, and 113)
- WSTF contaminated groundwater is NASA HQ's greatest liability (estimated at $350M).

Restoration Program

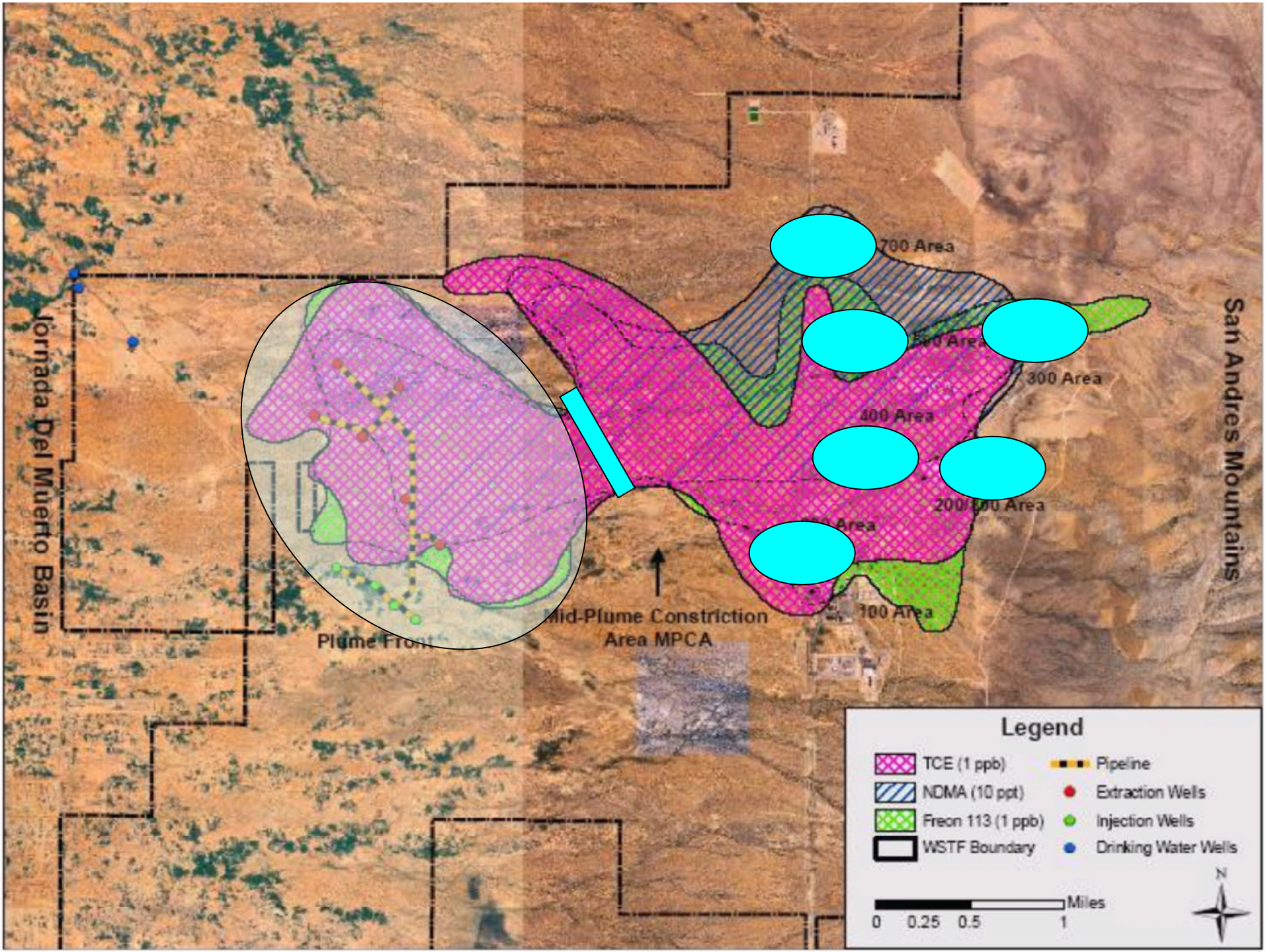
- Priority: Protect the public's health and the health of our workforce.
  - Containment
    - Stop the migration of contaminated groundwater
    - Address greatest health-risk liability first, then address source areas
      - Plume front
      - Mid-plume
      - Source areas
  - Restoration
    - Clean up the environment to preexisting conditions

Public and Employee Assessment

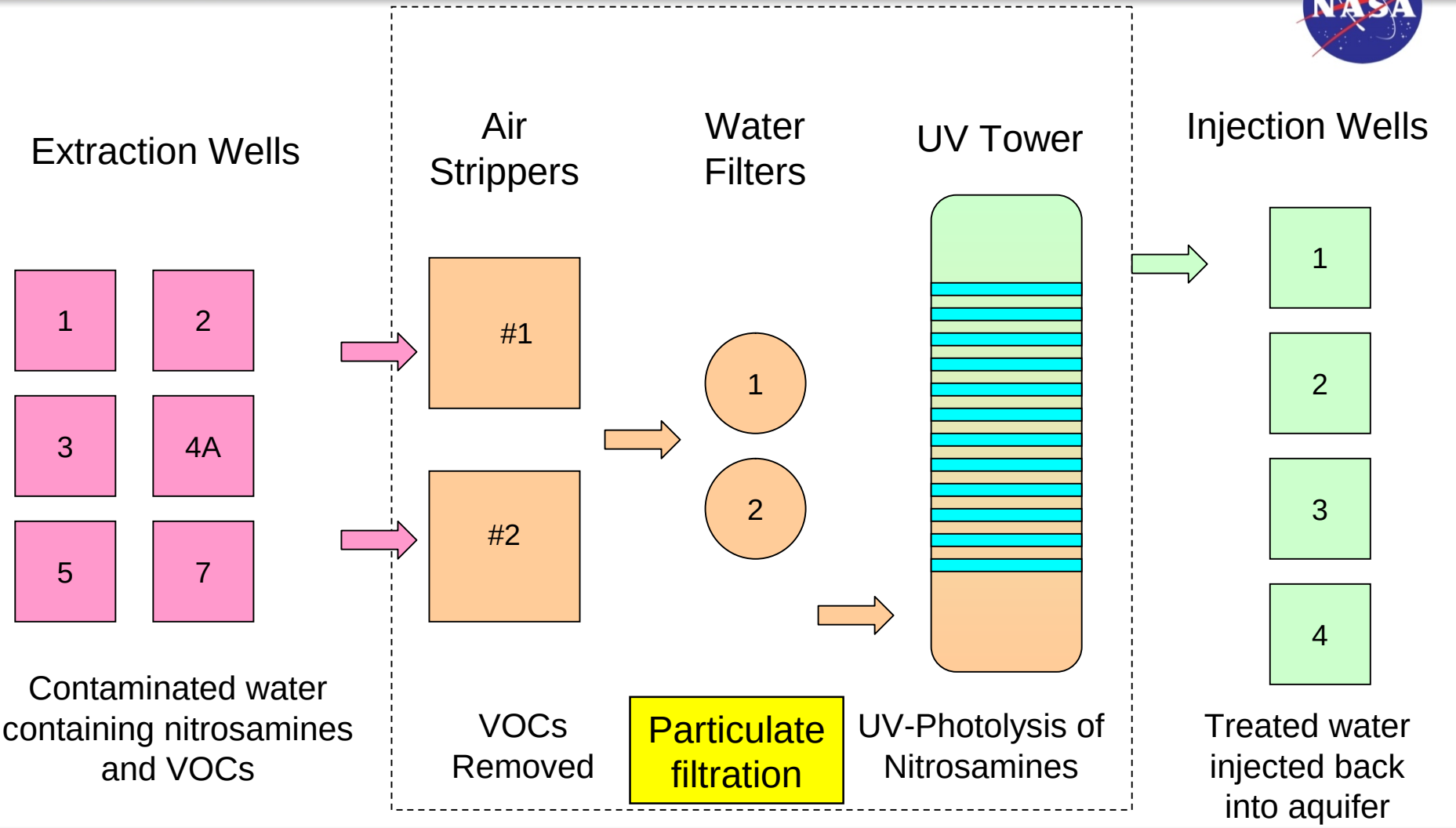
- No impact to any drinking water well
  - Includes public wells and NASA supply well
- No public exposure
  - Groundwater is several hundred feet below ground
  - No air or surface water exposure
  - Plume is moving very slowly west
    - Plume front treatment system will stop this westward movement.
- NASA performs on-going groundwater monitoring
  - More than 200 wells and zones routinely sampled
  - 850+ samples obtained monthly and analyzed for over 300 different contaminants

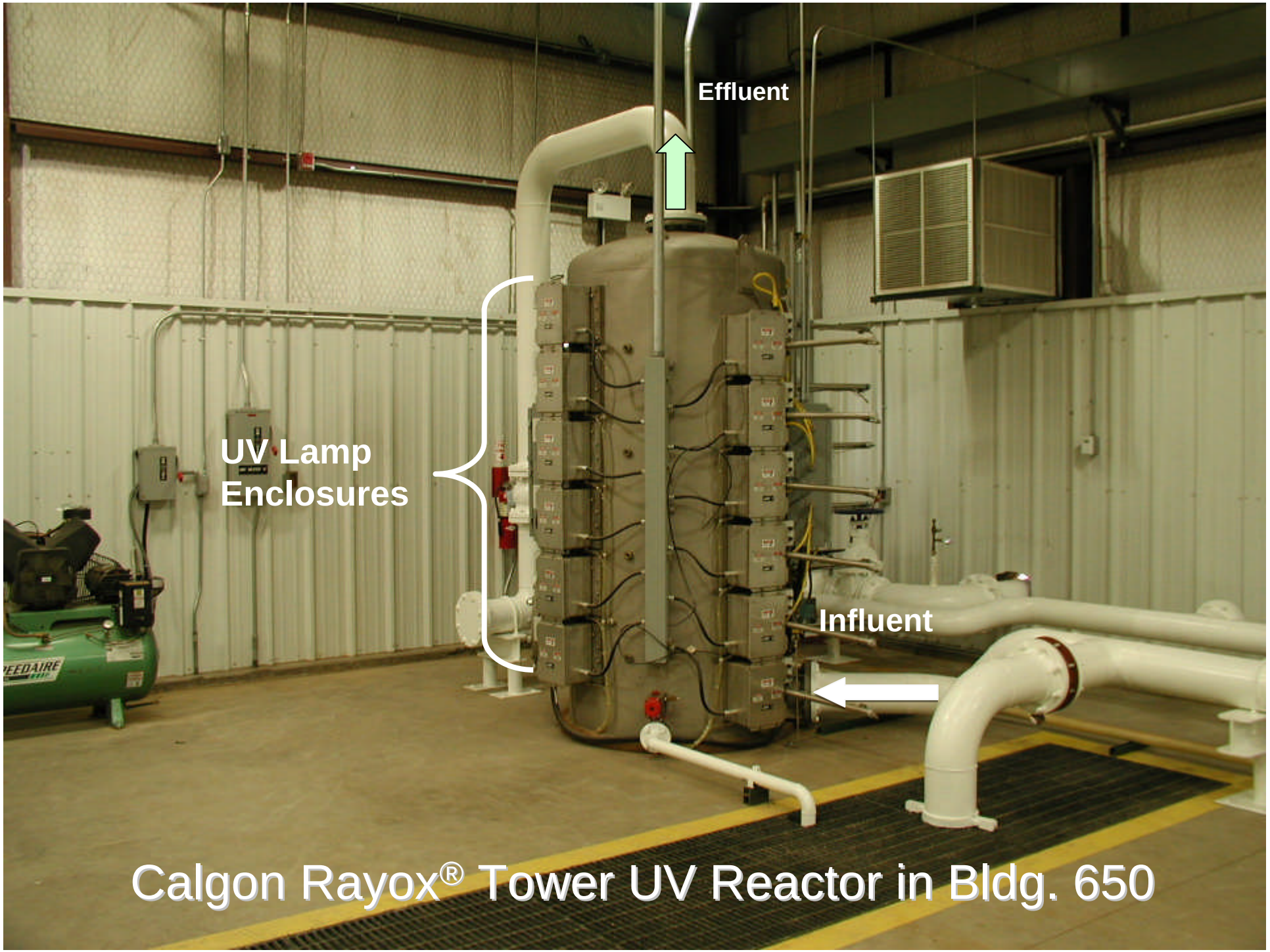
Containment and Restoration

- A Staged Approach over 60 years:
  - Attack the greatest risk to public health first
    - Stabilize the plume front (in progress)
  - Stop migration of contaminant into the plume front
    - Extraction and treatment at the Mid-Plume Constriction Area (~2009)
    - 100% design review completed, Construction start January 2009
  - Stop migration into the Mid-Plume Constriction Area
    - Clean up the source areas (~2012-2015)


700 Area
300 Area
400 Area
100 Area
Jornada Del Muerto Basin
San Andres Mountains
Plume Front
Mid-Plume Constriction
Area MPCA
Legend
TCE (1 ppb)
NDMA (10 ppt)
Freon 113 (1 ppb)
WSTF Boundary
Pipeline
Extraction Wells
Injection Wells
Drinking Water Wells
Miles
0 0.25 0.5 1
N

Plume Front Treatment System

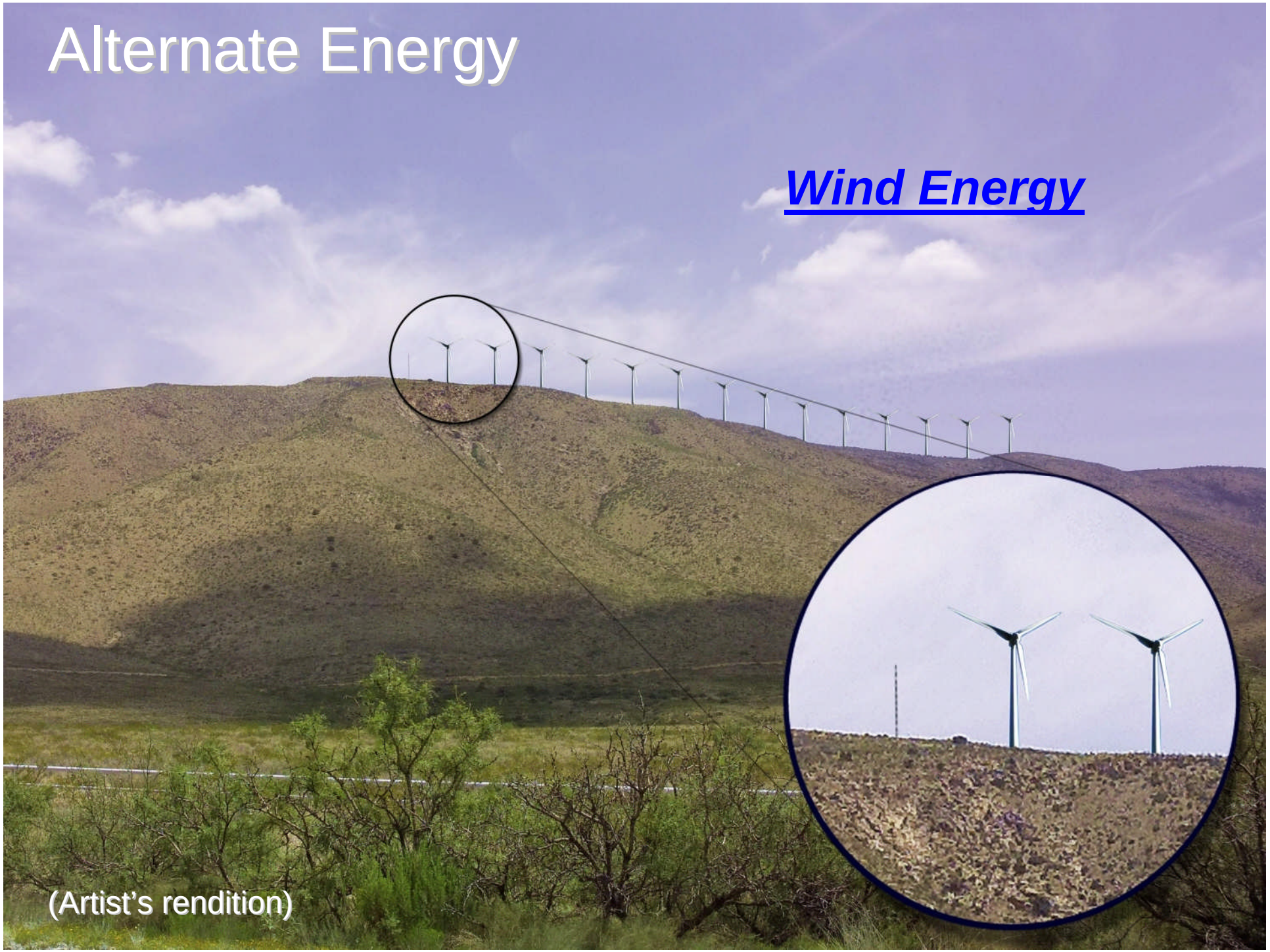




Calgon Rayox® Tower UV Reactor in Bldg. 650

Alternate Energy

Wind Energy



(Artist's rendition)

Alternate Energy

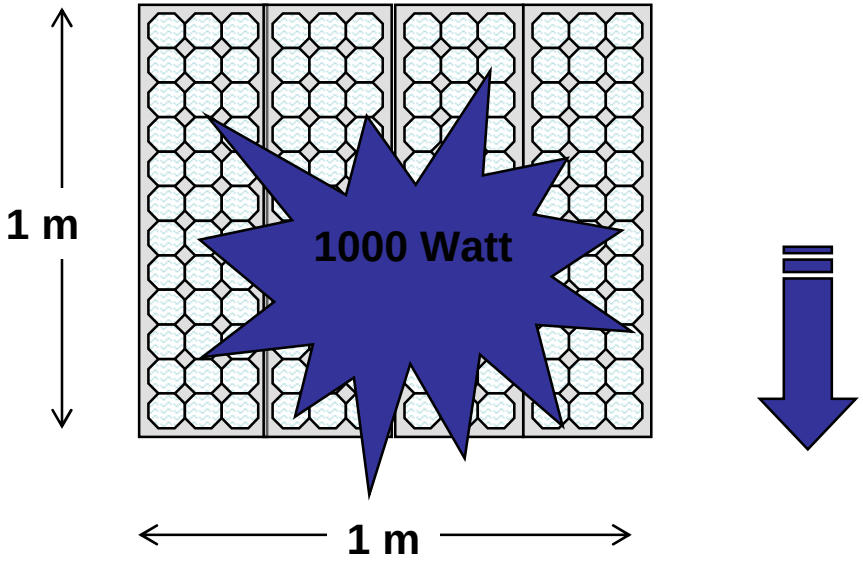
- **Wind Energy**
  - Quartzite Mountain monitored since 2005
  - Determined to be a class 4 to class 5 wind site
  - Initial Environmental Assessment (EA) performed by WSTF Environmental
  - Issues associated with EA:
    - Bat study (Fall 2007/Spring 2009)
    - Radar issues with WSMR (formed working group with WSMR test operations)
    - Cost for road to access planned wind farm about $5-6 M
  - Developers interested in constructing wind and solar
  - El Paso Electric Company (EPEC) interested in future wind project

Photovoltaic System

- Photovoltaic (PV) system will provide peak shaving during daylight hours
- Charge storage batteries
- Provide peak shaving
- Provide shading for vehicles in parking lot
- Provide plug-in for Privately Operated Vehicles (POVs)
- Could be used for PV test bed
  - Installation of separate modules (different technologies)

Efficiency of PV modules

- Commercial modules: 10-22 %

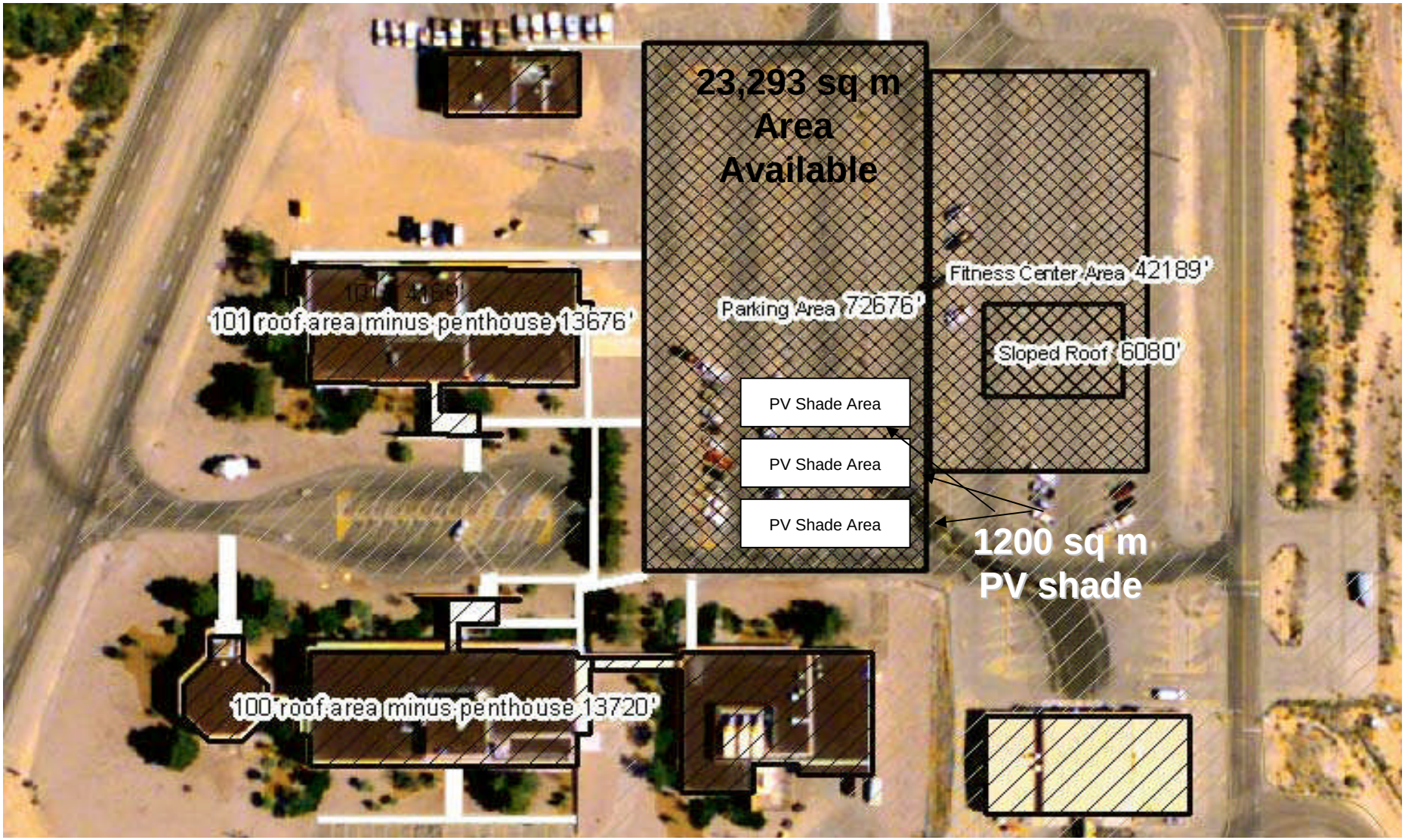


Irradiance = 1000 Watt/m^2

100 - 220 Watts
Electrical power

Shaded PV Structure Plan View

N



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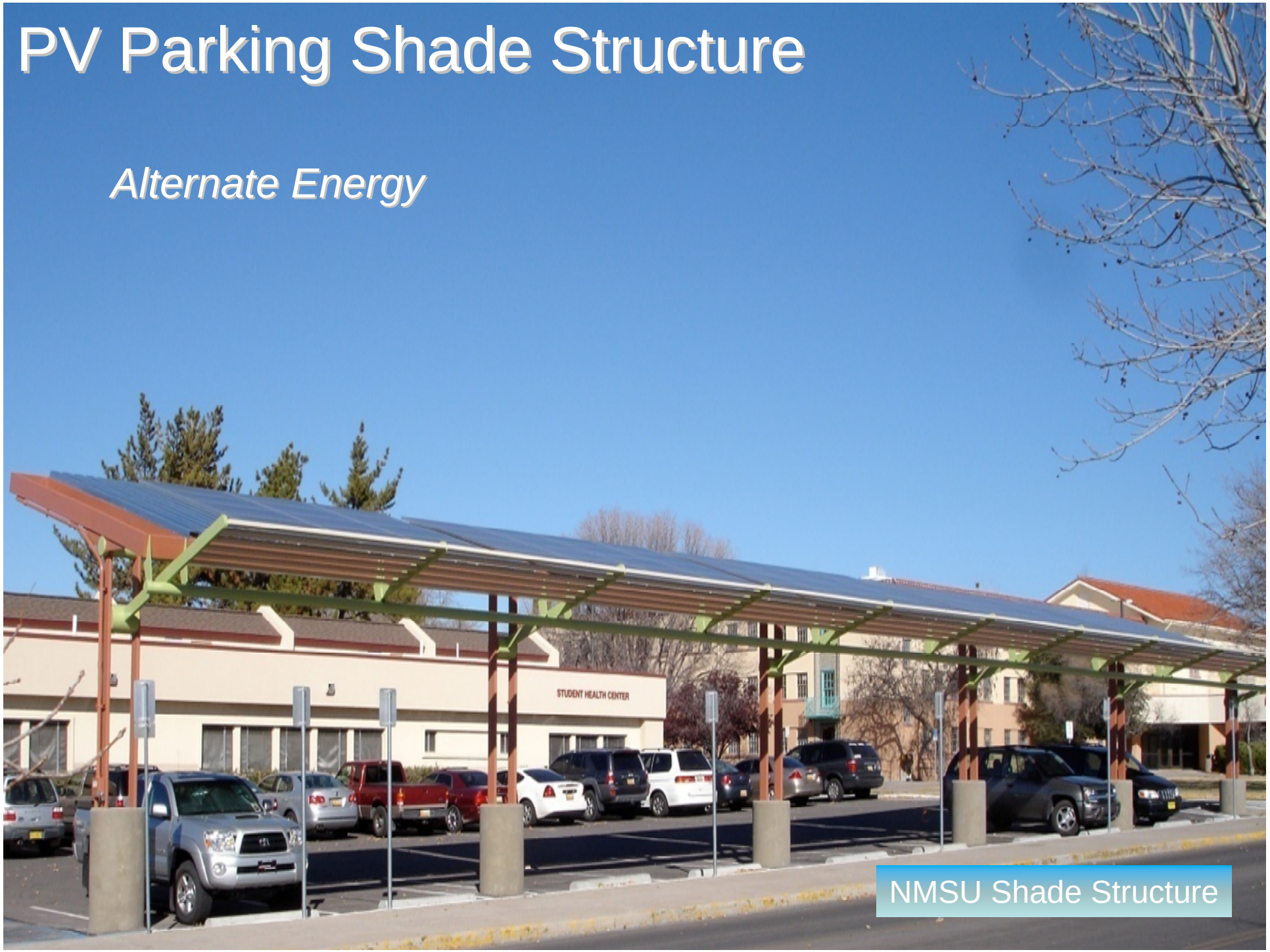
PV Parking Shade Structure

Alternate Energy



NMSU Shade Structure

PV/Battery Hybrid System

Test Bed Renewable System

- Charges batteries throughout the day during off-peak load demand
- Discharges batteries during peak load demand
  - Determines benefits of using Flow batteries for utility peak shaving application
  - Evaluates the economic benefits of the system and monitoring the operation and performance of the PV and batteries (Zinc-Bromine/Vanadium)
  - Collects data to evaluate overall system performance over time, and to verify the storage system operates when necessary and provides necessary power required by end user

Energy Storage Unit

50 kWh Zinc Bromine Battery Module

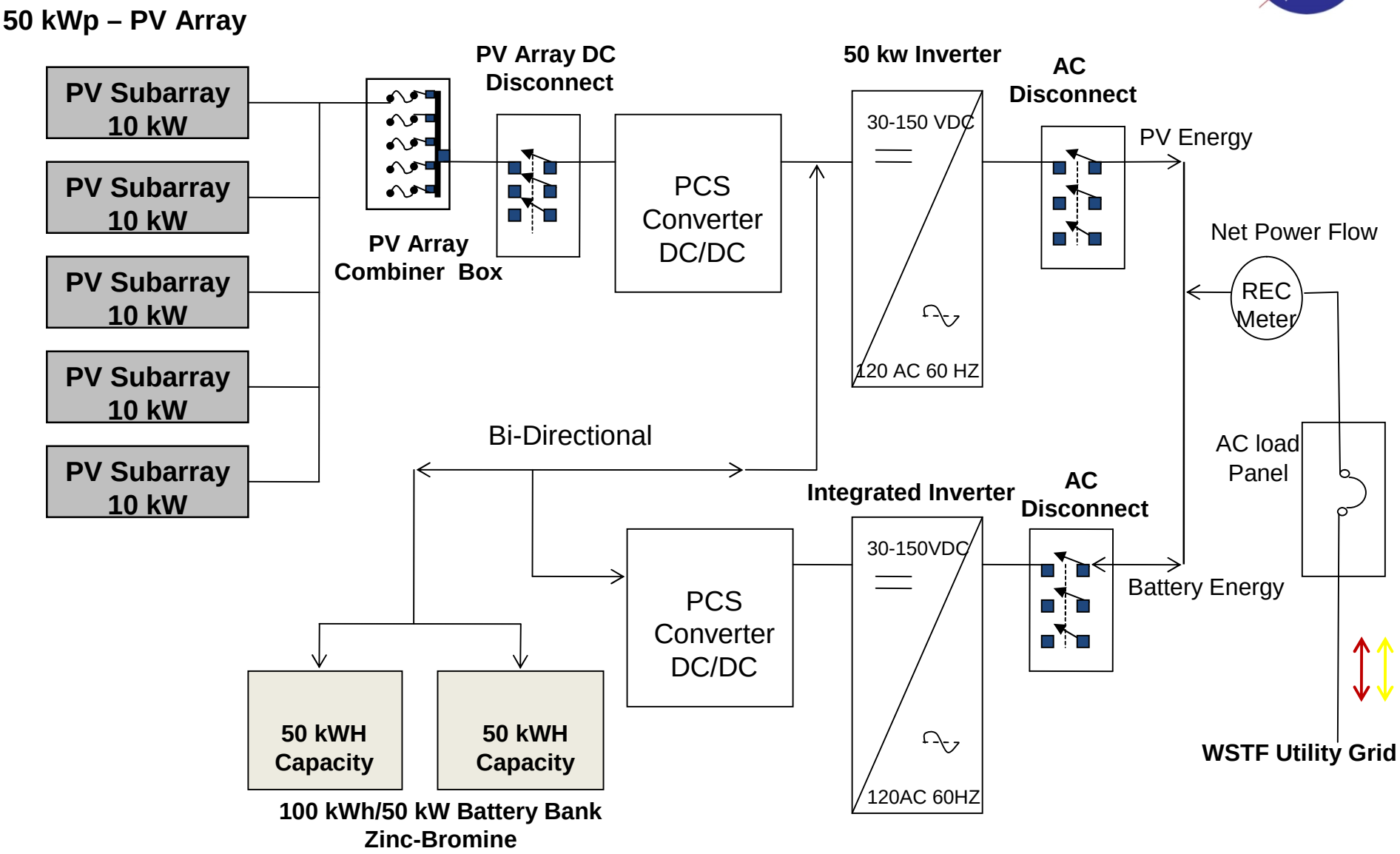
Battery Bank

- Two 50 kWh battery modules connected electrically in parallel
- A control system (Power Conversion System (PCS) inverter)
- A pair of electrolyte storage tanks
- Electrolyte circulation equipment

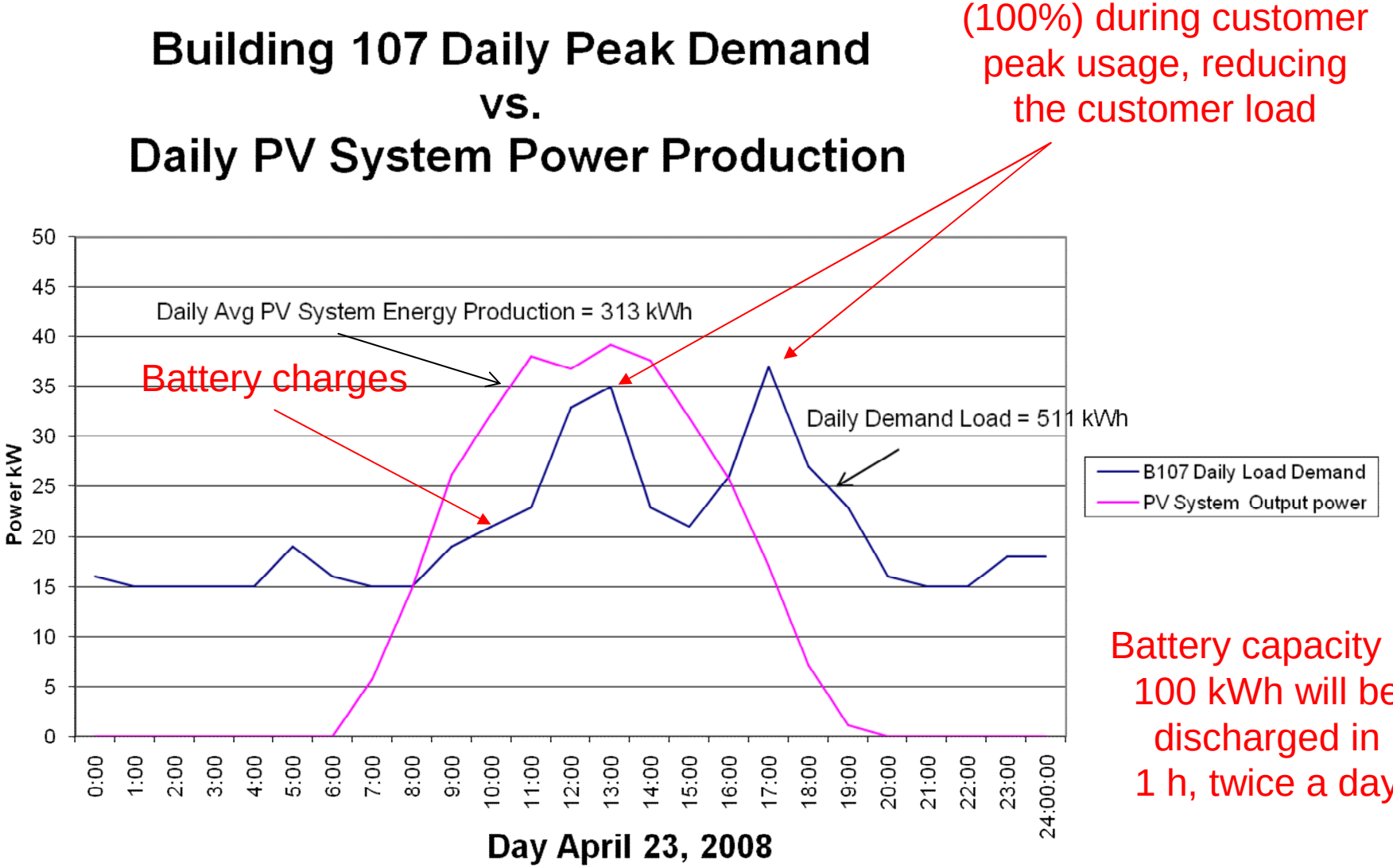
Advantages

- Uses electrodes that do not take part in the reactions, consequently there is no material deterioration that would cause long term loss performance
- Rapid recharge (2-4 hours)
- Deep discharge capability (100%)
- Built-in thermal management system
- Can be used for large scale application

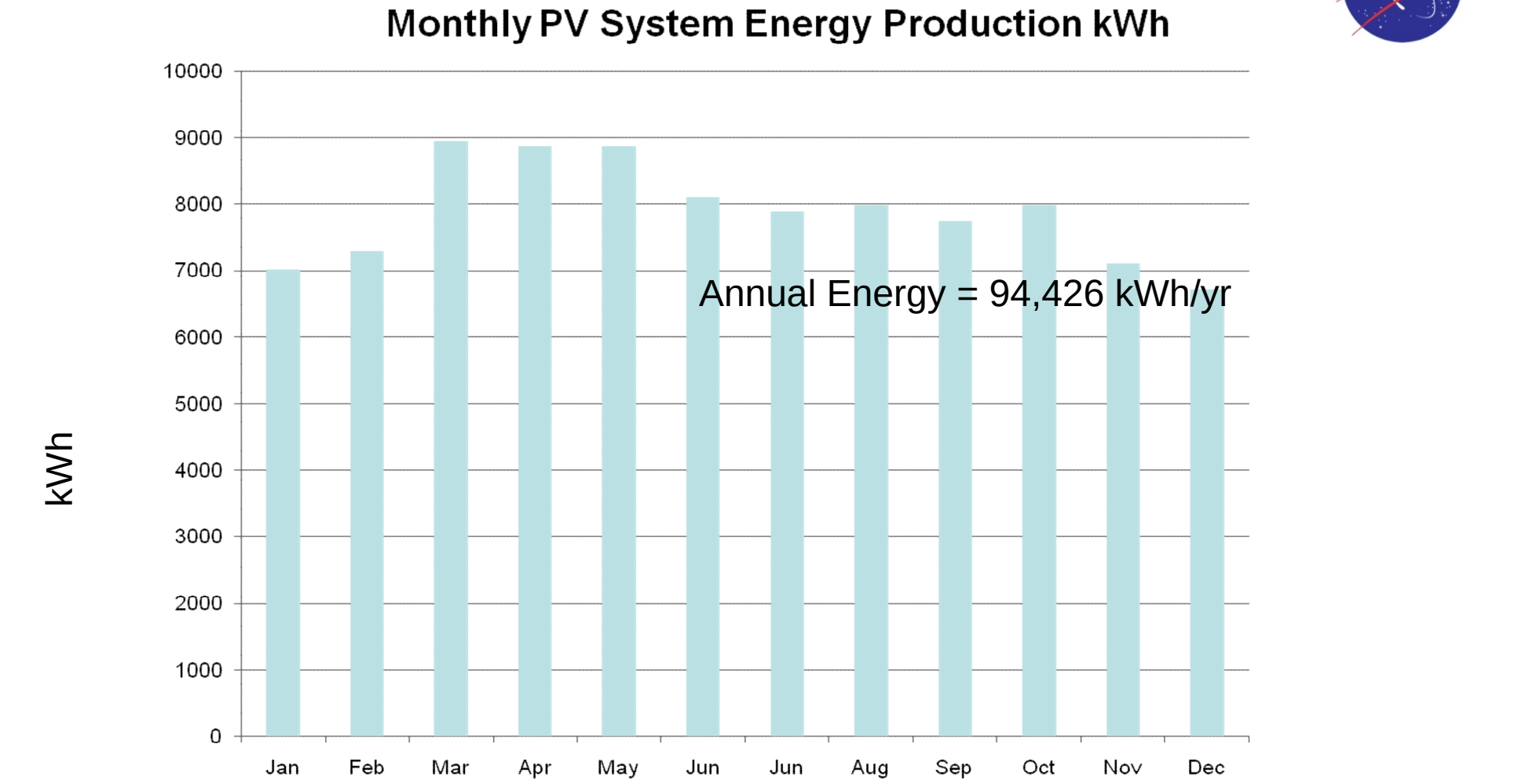
PV/Battery Hybrid System for Energy Storage Use



PV Power Coincides with Peak Demand Load



System Energy Production



Alternate Energy

Utility-size Solar Peak Shaving

Nevada Solar One

Peak Shaving Solar Plant

- NASA-owned land at WSTF considered for a solar-power generation plant
  - Approximately 400 acres
- Plant will be built and operated by the developer
- Developer is responsible for ALL financing of design, construction, and operation

Peak Shaving Solar Plant

- Current Electrical Power to WSTF
  - 69kV Transmission line to Apollo Substation from El Paso Electric Company
  - Substation rated for 15 MW (reached capacity in June 2006)
  - 24kV distribution line down to NASA land area
- NASA needs power to support site
  - Currently NASA has a ~5.5 MW peak load
  - DOD installation on site also interested in renewable energy

Peak Shaving Solar Plant

- Preliminary Environmental Assessment (EA) has been completed, but a complete EA is required prior to construction start
- NASA facility-type support is available, but cost is associated

Peak Shaving Solar Plant

- RFI on GovBiz (14 responses)
  - Number: 2008LUA
  - Posted Date: May 14, 2008
  - Response Date: May 27, 2008
  - 14 responses received
- Industry Day on Aug 12, 2008
  - MMA Renewable Ventures, LLC
  - Abencs/Abengoa
  - Acciona
  - International Power America
  - EverGuard Roofing, LLC
  - Greenlight Sunstream Holdings, LLC (dba Helios Energy)
  - Consolidated Solar Technologies
  - North Wind, Inc.
  - Juwi Solar

Peak Shaving Solar Plant

- New website for vendors generated
- In process of posting project information and Q&A
- Working with National Renewable Energy Laboratory (NREL) and New Mexico State University (NMSU) on the Request for Proposal (RFP)
- Options:
  - Provide land to El Paso Electric Company for 92 MW Concentrating Solar Power (CSP) plant
  - Sell power to Public Service Company of New Mexico (PNM) or other New Mexico utilities
  - Sell power out-of-state
  - Use power only behind the meter (NASA, White Sands Missile Range (WSMR), Holloman Air Force Base (HAFB), Fort Bliss)

Questions?

Component Description

- **PV Solar Modules:** 189 total, 265 Wp each. Will provide shade for 1,200 m² (~13000 ft²).
- **Balance of Systems**
  - 2 Power Conditioning Unit for battery voltage control to manage power delivery bi-directional. Manage the charge and discharge rates of battery and ensure compliance with utility harmonics standards.
- **Inverter:** Utility Interactive 50 kW rating
  - Zinc Bromine Battery package has integrated utility inverter built in.
- **Batteries (Zinc Bromine):** 2-50 kW battery bank for total of 100 kWh storage capacity.
  - Batteries will be programmed to discharge during customer peak (weekday) usage, thereby reducing customer demand charges.
- **Data Acquisition System**
  - The DAS system will monitor real-time PV production, customer load, battery state of charge, charging, and discharging voltages and currents.
  - Campbell Scientific datalogger

Energy Production Summary

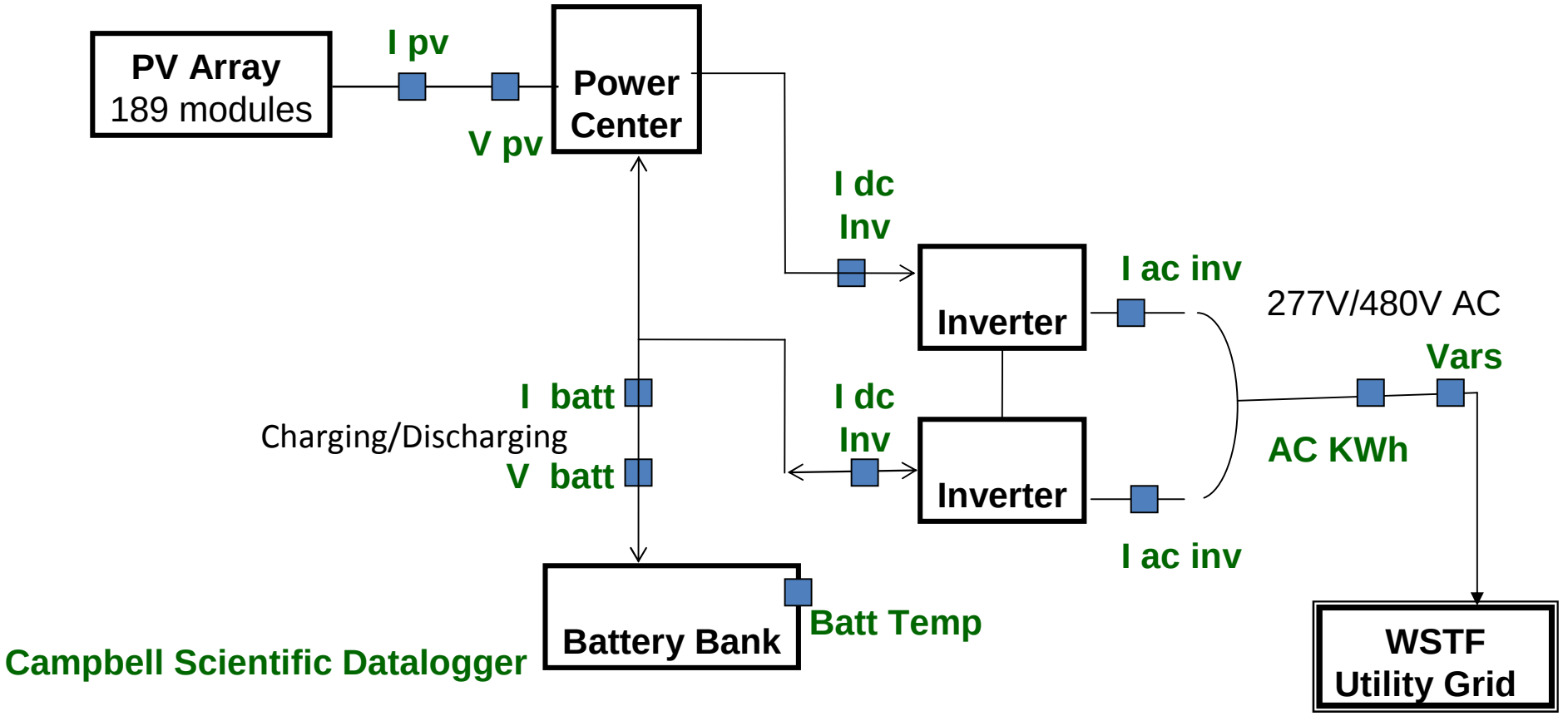
PV Production		
Quantity	**Value**	**Units**
Rated Capacity	50	kW
Mean Output	294	kWh/day
Capacity Factor	24.5	%
Total Production	94426	kWh/year

Battery		
Quantity	**Value**	**Units**
Rated Capacity	50	kW
Usable Storage Capacity	100	kW
Discharging	4	Hr
Energy Out	154	kWh/day
Round Trip Efficiency	77	%
Battery losses	23	%

Environmental Benefits - Emissions		
Pollutant	**Value**	**Units**
Carbon Dioxide	36,557	Kg/yr
Carbon Monoxide	0	Kg/yr
Sulfur dioxide	158	Kg/yr
Nitrogen Oxide	77.5	Kg/yr

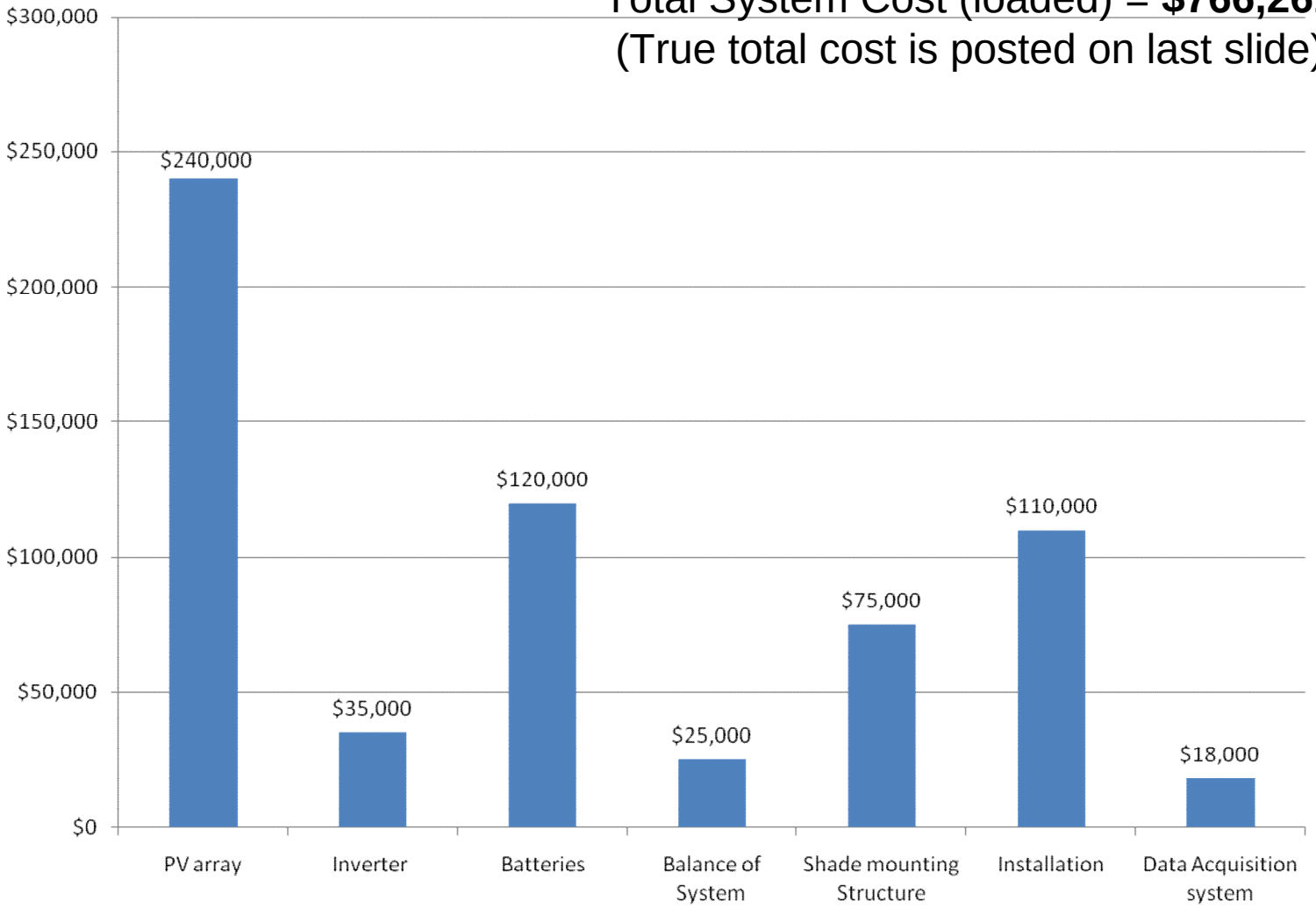
System Performance Monitoring

- Data Acquisition System Parameters – One-line diagram



System Component Cost Breakdown

Total System Cost (loaded) = **$766,261**
(True total cost is posted on last slide)



Note: Costs displayed for each component is NOT loaded

Summary

System Architecture	
Total Area	1,200 m² (~13,000 ft²)
PV Array Rating	50 kW (~ 189 PV modules of 265 Wp)
Battery Bank	100 kWh Capacity (2-50 kW modules)
Cost Breakdown	
PV Array Modules	$240K
Inverter	$35K
Batteries Zinc Bromine	$120K
Balance of System	$25K (2 power conditioning unit)
Shade Parking Structure	$75K (~$20Kto $30K per 18 kW array)
Installation	$110K
Data Acquisition System	$18K (hardware only)
Cost Per Watt Installed	$12.46/Watt (PV/Battery application--$8/Watt PV only)
Total Loaded Cost of System	**$766,261**
Annual Energy Production	
AC Energy Production	94,426 kWh (output of PV/Battery System)
* Capacity Factor	24.0%
Levelized Cost of Energy	$0.25 kW/h (cost to produce energy kWh)

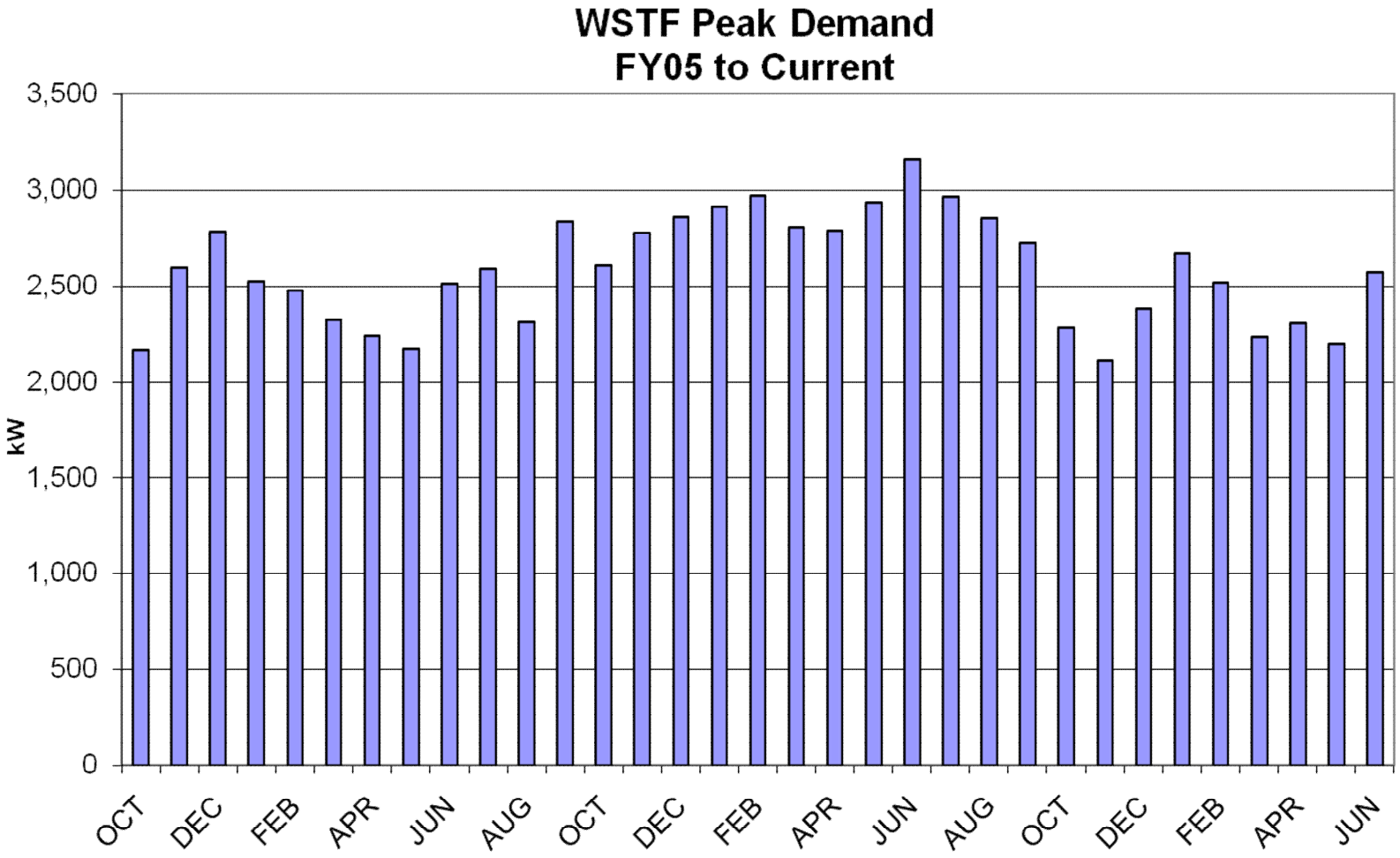
New Technologies

- Implement renewable initiatives by combining the best technologies to arrive at most efficient system(s):
  - Solar power photovoltaic (PV) system
  - Geothermal heat pump systems
  - Wind generated power
  - Solar powered thermal system
  - Hydrogen
  - Fuel cells
  - Hybrid systems

5 Year Long-Term Goals

- Develop a solar powered PV farm for providing electrical power to WSTF and sell surplus power to utility companies.
- Develop 3 MW of wind-generated power with wind farm on top of Quartzite Mountain.
- Utilize geothermal heat pump systems for WSTF's heating and cooling to greatly reduce utility costs.
- Provide renewable energy test beds for supporting future Orion energy requirements.

WSTF's Peak Demand Load



WSTF's Peak Demand and PV System Production

PV Power Vs. WSTF Peak Demand Load